Measuring Pinhole Leaks – A Novel Method
By Carol Dunn

If you have ever visited the John F. Kennedy Space Center and had the opportunity to visit the Shuttle launch pads, you will have seen the large liquid hydrogen tanks sitting at the edge of the pads. You just cannot miss them. These huge behemoths are capable of holding 800,000 gallons of liquid hydrogen and were built during the Apollo era in 1965. That makes them 40 years old. Composed of an inner and outer sphere, the annular region is evacuated and filled with perlite, a powder-like insulation. Forty support rods suspend the inner sphere to the outer sphere. The overall design of these huge spheres are themselves a testament to man's ingenuity and inventiveness, when you consider how big they are and how long these tanks have been doing their job in one of the most corrosive atmospheres on earth.

Both of the shuttle pads have one of these large tanks and the Shuttle program is currently using both pads. However, just recently, there has been increasing concerns over possible air leaks from the outside into the evacuated region. As with many other situations encountered by the space program, this question posed NASA's scientists and technicians with a unique set of circumstances and difficulties. Until recently, it was not known just how to detect these leaks. However, inventors Dr. Bob Youngquist, Stan Starr, and Dr. Mark Nurge came up with an ingenious and elegant solution of detecting and estimating such a leak by measuring the change in the boil-off rate of the liquid hydrogen in the tank.

Sounds simple, yet they ran through numerous ideas before coming up with this solution. Trying to measure by pressure does not work, since the inner tank holds liquid hydrogen, which is below the freezing point of air, so the trapped air will in time, pass by the inner tank surface and freeze out onto it, so the pressure increase is minimal. Measuring the mass flow rate does not work either. If one assumes that there is a small, 10 standard cubic centimeters per second (sccs), air leak into the evacuated region of one of the Pad LH2 tanks, the leak rate corresponds to a mass flow of about 1kg/day of air. If this ends up on the inner shell, it will only increase its mass by about 370kg/year—a minor increase in the weight of the shell. It also corresponds to only a 0.03-inch think layer per year (assuming it freezes uniformly over the lower half of the inner shell), again only a minor concern.

However, as this air freezes, it gives up heat to the inner tank shell, causing about 4 gallons of hydrogen to boil away. An optimal tank boils about 200 gallons of LH2 per day due to heat transfer, so losing an additional 4 gallons per day is discernable by sensors built with present day technology. Pinhole leaks due to corrosion would grow with time and could very quickly scale up, increasing the boil-off in a linear fashion. A 100 sccs leak would boil 40 gallons per day, a 20% increase in the ideal rate.

The Constellation Program Engineering Review Board was convinced by this argument and requested that a better boil-off detection system be implemented to improve the existing system. As a result, an improved sensor system has been certified and will be implemented once the Constellation Program acquires ownership of the Pad B LH2 tank. Meanwhile, users understand that any increases in boil-off detected by the existing boil-off detection system could be indicative of a pinhole leak of air into the tank.

It is interesting to note that the original design for these tanks included a stairwell to be welded to the outside of the tanks. These weld points caused corrosion, and so the stair well was removed. These old corrosion points as well as others are places where pinhole leaks could develop. Another problem is perlite migration, which causes voids between the outer and inner tank. However, analyses, IR imaging, and boil-off data show condensation and increased hydrogen boil off, which all indicate changes that should be looked at by engineers. Without this solution, a pinhole leak could go undetected for months. The potential savings here is in the hundreds of thousands of dollars and could potentially increase the life of the tanks. Constellation will use the existing liquid hydrogen tanks and will need even more liquid hydrogen storage (at least at Pad A), so this concept will be used throughout the program.

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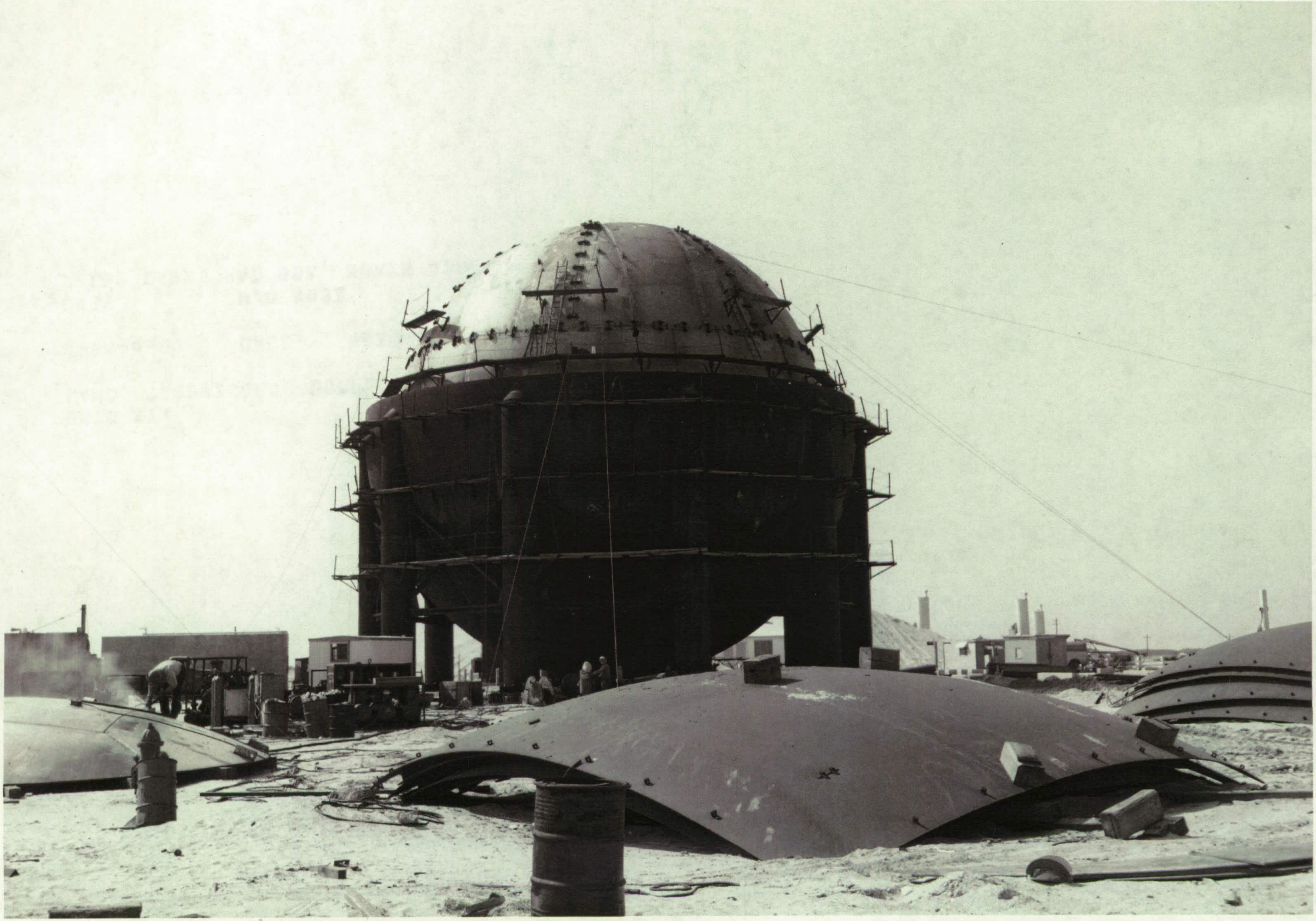


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